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DESCRIPTION

IMAGE DISPLAY APPARATUS AND CONTROL METHOD THEREFOR

TECHNICAL FIELD

The present invention relates to an image display apparatus and a
5 control method for use with such an image display apparatus, and more
particularly to an image display apparatus using pixel display elements that are
current-driven based on gradation pixel data, such as an organic EL
(electroluminescence) display, for example, a control method for use with such
an image display apparatus, a drive circuit for causing current control elements
10 such as organic EL elements to emit light in such an image display apparatus,
and a drive method for the drive circuit.

BACKGROUND ART

Image display apparatus using pixel display elements that are driven
under current control, such as organic EL displays or the like, have drive
15 circuits associated with respective pixels of driving those pixel display elements,
i.e., current control elements. The drive circuits are arrayed two-dimensionally
in association with the respective pixels, making up the image display
apparatus. In each of the drive circuits, gradation pixel data is written from a
signal line through a selection transistor into a holding capacitor which is
20 connected between the gate and source of a drive transistor. The pixel data is
held in the holding capacitor during a display period. A signal charge
corresponding to the display luminance of the pixel is written in the holding
capacitor, and a current depending on the signal charge is supplied from the
drive transistor to the pixel display element.

25 Heretofore, an image display apparatus of the type described above

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comprises, as shown in FIG. 1, display panel 10, control circuit 20, signal line driver 30, and scanning line driver 40. Display panel 10 comprises an organic EL display, for example, and has a plurality of signal lines $X_1, \dots, X_i, \dots, X_n$ to which gradation pixel data D are applied, a plurality of scanning line $Y_1, \dots, Y_j, \dots, Y_m$ to which scanning signals V are applied, and a plurality of pixels 10_{ij} ($i = 1, 2, \dots, n, j = 1, 2, \dots, m$) disposed at points of intersection between signal lines $X_1, \dots, X_i, \dots, X_n$ and scanning line $Y_1, \dots, Y_j, \dots, Y_m$. Of pixels 10_{ij} , those pixels on scanning lines that are selected by scanning signals V are supplied with gradation pixel data D to display an image.

Control circuit 20 supplies image input signal VD supplied from an external source to signal line driver 30 and also supplies vertical scanning signal PV to scanning line driver 40. Signal line driver 30 applies gradation pixel data D depending on image input signal VD to signal lines $X_1, \dots, X_i, \dots, X_n$. Scanning line driver 40 successively generates scanning signals V in synchronism with vertical scanning signal PV supplied from control circuit 2, and applies scanning signals V successively to corresponding scanning line $Y_1, \dots, Y_j, \dots, Y_m$ of display panel 10.

FIG. 2 is a circuit diagram showing an electric arrangement of pixel 10_{ij} (e.g., $i = 3, j = 2$) in FIG. 1.

Pixel $10_{3,2}$ comprises power line 11, ground line 12, selection transistor $13_{3,2}$ in the form of an n-channel MOS field-effect transistor (FET) (hereinafter referred to as "nMOS"), holding capacitor $14_{3,2}$, drive transistor $15_{3,2}$ in the form of a p-channel MOSFET (hereinafter referred to as "pMOS"), pixel display element $16_{3,2}$ as a current control element, and parasitic capacitor $17_{3,2}$. Other pixel 10_{ij} , such as pixels $10_{4,2}, 10_{5,2}$ (not shown), that are positioned adjacent to

pixel $10_{3,2}$ are of the same structure. Selection transistor $13_{3,2}$, holding capacitor $14_{3,2}$, drive transistor $15_{3,2}$, pixel display element $16_{3,2}$, and parasitic capacitor $17_{3,2}$ make up a drive circuit. The pixel display element should preferably comprise an organic EL element, for example.

- 5 Selection transistor $13_{3,2}$ has a gate electrode connected to a selection line (not shown), a drain electrode to signal line X_3 , and a source electrode to the gate electrode of drive transistor $15_{3,2}$. Holding capacitor $14_{3,2}$ is connected between the gate electrode of drive transistor $15_{3,2}$ and power line 11. Drive transistor $15_{3,2}$ has its gate electrode connected to the source electrode of
- 10 selection transistor $13_{3,2}$ and one end of holding capacitor $14_{3,2}$, a source electrode connected to power line 11, and a drain electrode to the anode of pixel display element $16_{3,2}$. Pixel display element $16_{3,2}$ is connected between the drain electrode of drive transistor $15_{3,2}$ and ground line 12, and emits light at a luminance depending on current $IL_{3,2}$ from drive transistor $15_{3,2}$. Parasitic
- 15 capacitor $17_{3,2}$ comprises a parasitic capacitor across pixel display element $16_{3,2}$.

- In pixel $10_{3,2}$, during a selection period, i.e., when scanning signal V is applied to scanning line Y_2 , selection transistor $13_{3,2}$ is turned on, applying gradation pixel data D applied to signal line X_3 between the gate and source of drive transistor $15_{3,2}$. At this time, holding capacitor $14_{3,2}$ is charged. Then,
- 20 when the selection period changes to a non-selection period, selection transistor $13_{3,2}$ is turned off. Since the gate-to-source voltage VGS of drive transistor $15_{3,2}$ is held by holding capacitor $14_{3,2}$, current $IL_{3,2}$ depending on written gradation pixel data D remains to be continuously supplied from drive transistor $15_{3,2}$ to pixel display element $16_{3,2}$ during the non-selection period.
- 25 Pixel $10_{4,2}$, $10_{5,2}$ and the like that are positioned adjacent to pixel $10_{3,2}$ operate in

the same manner.

The above conventional image display apparatus has suffered the following problems:

As shown in FIG. 3, drive transistor 15_{3,2} of pixel 10_{3,2}, drive transistor 15_{4,2} of pixel 10_{4,2}, and drive transistor 15_{5,2} of pixel 10_{5,2} have their respective VGS-IDS (gate-to-source voltage vs. drain-to-source current) characteristics that vary from pMOS to pMOS. In particular, their threshold values widely vary from each other such that even when identical gradation pixel data D are applied between the gates and sources of drive transistors 15_{3,2}, 15_{4,2}, 15_{5,2}, they have different drain-to-source currents IDS IL_{3,2}, IL_{4,2}, IL_{5,2}. Therefore, since different current flow respectively through pixel display element 16_{3,2} of pixel 10_{3,2}, pixel display element 16_{4,2} of pixel 10_{4,2}, and pixel display element 16_{5,2} of pixel 10_{5,2}, pixel display elements 16_{3,2}, 16_{4,2}, 16_{5,2} emit light at different luminances. During the non-selection period, since the gate-to-source voltages VGS of those drive transistors are held by the corresponding holding capacitors, even though gradation pixel data D are identical, different currents based on the variations of the drive transistors are caused to continuously flow to the current control elements by the drive circuits.

As described above, the conventional image display apparatus is problematic in that even when identical gradation pixel data, i.e., signal voltages, are written, the current control elements emit light at different luminances, lowering the quality of the displayed image.

R. Dawson, et al. have proposed a drive circuit, to be described below, for preventing drive current variations from occurring due to threshold value variations of drive transistors (R. Dawson, et al., "A Poly-Si Active-Matrix OLED

Display with Integrated Drivers," SID' 99 DIGEST, pp. 11-14).

FIG. 4 shows an arrangement of a drive circuit for a current control element proposed by R. Dawson, et al. As shown in FIG. 4, the drive circuit for the current control element comprises selection transistor 24A, holding capacitor 25, drive transistor 26, current control element 27, parasitic capacitor 28, decoupling capacitor 29, and switching transistors 31, 32, which are connected between power line 21, ground line 22, and signal line 23.

Selection transistor 14A comprises a pMOS and has a gate electrode connected to a selection line (not shown), a source electrode to signal line 23, and a drain electrode to one end of decoupling capacitor 29. Holding capacitor 25 is connected between the gate electrode of drive transistor 26 and power line 21. Drive transistor 26 comprises pMOS and has its gate electrode connected to the other end of decoupling capacitor 29 and one end of holding capacitor 15, a source electrode to power line 11, and a drain electrode to the source electrode of switching transistor 32.

Current control element 27 is connected between the drain electrode of switching transistor 32 and ground line 22, and emits light at a luminance depending on a current from drive transistor 26. Parasitic capacitor 28 comprises a parasitic capacitor across current control element 27. Decoupling capacitor 29 is connected between the drain electrode of selection transistor 24A and the gate electrode of drive transistor 26, and isolates selection transistor 24A and drive transistor 26 from each other in terms of direct currents. Switching transistor 31 comprises pMOS and has a gate electrode connected to a resetting line (not shown), a source electrode to the gate electrode of drive transistor 26, and a drain electrode to the drain electrode of drive transistor 26.

Switching transistor 32 comprises pMOS and has a gate electrode connected to the resetting line, a source electrode to the drain electrode of drive transistor 26, and a drain electrode to one end of current control element 27.

FIG. 5 is a timing chart illustrative of the manner in which the drive circuit of the conventional current control element shown in FIG. 4 operates.

Operation of the drive circuit of the conventional current control element shown in FIG. 4 will be described below.

Before a selection period starts, the drive circuit shown in FIG. 4 is required to discharge parasitic capacitor 28 of current control element 27 to set drain voltage V_D of drive transistor 26 to the ground line potential. The voltage of signal line 23 is set to voltage V_{DD} of power line 21.

When the selection period starts, a row selection signal is given to the selection line to turn on selection transistor 24A, and a resetting signal is given from a resetting driver (not shown) to the resetting line to turn on switching transistor 31 and turn off switching transistor 32. The gate and drain electrodes of drive transistor 26 are electrically connected to each other, starting to discharge holding capacitor 25. When a sufficient time elapses, gate voltage V_G of drive transistor 26 drops to threshold value V_T . Thereafter, switching transistor 31 is turned off, floating the gate electrode of drive transistor 26.

Then, when the input voltage from signal line 23 switches from voltage V_{DD} of power line 21 to write voltage V_{DATA} , gate-to-drain voltage V_{GS} of drive transistor 26 is determined by a capacitance division between capacitance value C_D of decoupling capacitor 29 and capacitance value C_S of holding capacitor 25, according to the following equation:

$$V_{GS} = V_G - V_{DD}$$

$$= V_T + C_D \cdot (V_{DATA} - V_{DD}) / (C_S + C_D) \quad (1)$$

However, the drain-to-source current of a transistor is generally expressed by a function of $(V_{GS} - V_T)$. Since $(V_{GS} - V_T)$ is determined by V_{DATA} as can be seen from the above equation, a variation of the threshold value of drive transistor 26 is corrected.

The circuit shown in FIG. 4 requires four transistor for one pixel and also requires a decoupling capacitor in addition to a holding capacitor. Therefore, the aperture of the pixel is reduced, resulting in manufacturing process difficulty. If the value of decoupling capacitance C_D is small, then write voltage V_{DATA} needs to be increased, and it is desirable to achieve the relationship $C_D > C_S$. To meet such a demand, a chip area for forming decoupling capacitance C_D is increased. Another shortcoming is that it takes time to discharge the parasitic capacitor of the current control element prior to the selection period, and it needs a complex operation to discharge the parasitic capacitor.

15 DISCLOSURE OF THE INVENTION

It is an object of the present invention to provide an image display apparatus for suppressing light emission luminance variations of respective pixel display elements to increase the quality of the displayed image.

Another object of the present invention is to provide a control method for use with such an image display apparatus.

Still another object of the present invention is to provide a drive circuit for a current control element, which is capable of correcting threshold value variations of drive transistors with a minimum of components.

Yet another object of the present invention is to provide a drive method for a drive circuit for a current control element, which is capable of correcting

threshold value variations of drive transistors with a minimum of components.

According to a first aspect of the present invention, an image display apparatus comprises a pixel having a drive transistor and a pixel display element which are connected in series between a first power line and a second power line, a holding capacitor connected to a gate electrode of the drive transistor, and a selection transistor connected between a signal line and the gate electrode of the drive transistor, control means for turning on the selection transistor thereby to write gradation pixel data in the holding capacitor from the signal line, discharging charges of the gradation pixel data written in the holding capacitor through the drive transistor for a predetermined time, and thereafter floating the gate electrode of the drive transistor thereby to hold the charges of the gradation pixel data stored in the holding capacitor.

According to a second aspect of the present invention, a control method for an image display apparatus including a pixel having a drive transistor and a pixel display element which are connected in series between a first power line and a second power line, a holding capacitor connected to a gate electrode of the drive transistor, and a selection transistor connected between a signal line and the gate electrode of the drive transistor, comprises the pixel data writing step of turning on the selection transistor thereby to write gradation pixel data in the holding capacitor from the signal line, the discharging step of discharging charges of the gradation pixel data written in the holding capacitor through the drive transistor for a predetermined time, and after the discharging step, the pixel data holding step of floating the gate electrode of the drive transistor thereby to hold the charges of the gradation pixel data stored in the holding capacitor.

According to a third aspect of the present invention, a drive circuit for a current control element comprises a drive transistor and a pixel display element which are connected in series between a first power line and a second power line, a holding capacitor connected to a gate electrode of the drive transistor, and a selection transistor connected between a signal line and the gate electrode of the drive transistor, wherein the selection transistor is turned on to input a first signal voltage from the signal line to discharge signal charges written in the holding capacitor through the drive transistor in a selection period of the drive circuit, thereafter a second signal voltage is input from the signal line and held in the holding capacitor, and the selection transistor is turned off to pass a current through the drive transistor to the current control element in a non-selection period of the drive circuit.

According to a fourth aspect of the present invention, a drive circuit includes a drive transistor and a pixel display element which are connected in series between a first power line and a second power line, a holding capacitor connected to a gate electrode of the drive transistor, and a selection transistor connected between a signal line and the gate electrode of the drive transistor, and the drive circuit is driven by a drive method which comprises the steps of turning on the selection transistor to input a first signal voltage from the signal line to discharge signal charges written in the holding capacitor through the drive transistor in a selection period of the drive circuit, inputting a second signal voltage from the signal line and holding the second signal voltage in the holding capacitor, and turning off the selection transistor to pass a current through the drive transistor to the current control element in a non-selection period of the drive circuit.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a block diagram of an electric arrangement of a conventional image display apparatus;

FIG. 2 is a circuit diagram showing an electric arrangement of a pixel in
5 the image display apparatus shown in FIG. 1;

FIG. 3 is a graph showing the IDS-VGS characteristics of drive transistors of respective pixels;

FIG. 4 is a diagram of an arrangement of a drive circuit for a conventional current control element;

10 FIG. 5 is a timing chart showing the manner in which the circuit shown in FIG. 4 operates;

FIG. 6 is a block diagram of an electric arrangement of an image display apparatus according to a first embodiment of the present invention;

FIG. 7 is a circuit diagram of an electric arrangement of a pixel and
15 pixels adjacent thereto in the image display apparatus shown in FIG. 6;

FIG. 8 is a timing chart showing the manner in which an image display section operates;

FIG. 9 is a graph showing the IDS-VGS characteristics of a drive transistor;

20 FIG. 10 is a graph showing the VL-IS characteristics of a pixel display element;

FIG. 11 is a graph showing the IDS-VGS characteristics of drive transistors of respective pixels;

25 FIG. 12 is a graph showing the transient characteristics of the gate-to-source voltage VGS of drive transistors of respective pixels;

FIG. 13 is a graph showing the transient characteristics of the drain currents I_{DS} of drive transistors of respective pixels;

FIG. 14 is a graph showing the I_{DS} - V_{GS} characteristics of drive transistors of respective pixels;

5 FIG. 15 is a graph showing the I_{DS} - V_{GS} characteristics of drive transistors of respective pixels;

FIG. 16 is a block diagram of an electric arrangement of an image display apparatus according to a second embodiment of the present invention;

10 FIG. 17 is a circuit diagram of an electric arrangement of a pixel in the image display apparatus shown in FIG. 16;

FIG. 18 is a timing chart showing the manner in which an image display section operates;

FIG. 19 is a block diagram of an electric arrangement of an image display apparatus according to a third embodiment of the present invention;

15 FIG. 20 is a diagram of an electric arrangement of a pixel in the image display apparatus shown in FIG. 19;

FIG. 21 is a timing chart showing the manner in which an image display section operates;

20 FIG. 22 is a block diagram of an electric arrangement of an image display apparatus according to a fourth embodiment of the present invention;

FIG. 23 is a timing chart showing the manner in which an image display section operates;

FIG. 24 is a block diagram of an electric arrangement of an image display apparatus according to a fifth embodiment of the present invention;

25 FIG. 25 is a diagram of an electric arrangement of a pixel in the image

display apparatus shown in FIG. 24;

FIG. 26 is a block diagram of an electric arrangement of an image display apparatus according to a sixth embodiment of the present invention;

FIG. 27 is a diagram of an electric arrangement of a pixel in the image display apparatus shown in FIG. 26;

FIG. 28 is a block diagram of an electric arrangement of an image display apparatus according to a seventh embodiment of the present invention;

FIG. 29 is a diagram of an electric arrangement of a pixel in the image display apparatus shown in FIG. 28;

FIG. 30 is a block diagram of an electric arrangement of an image display apparatus according to an eighth embodiment of the present invention;

FIG. 31 is a block diagram of an electric arrangement of an image display apparatus according to a ninth embodiment of the present invention;

FIG. 32 is a diagram of an electric arrangement of a pixel in the image display apparatus shown in FIG. 31;

FIG. 33 is a timing chart showing the manner in which an image display section operates;

FIG. 34 is a timing chart showing the manner in which an image display section operates;

FIG. 35 is a block diagram of an electric arrangement of an image display apparatus according to a tenth embodiment of the present invention;

FIG. 36 is a diagram of an electric arrangement of a pixel in the image display apparatus shown in FIG. 35;

FIG. 37 is a block diagram of an electric arrangement of an image display apparatus according to an eleventh embodiment of the present

Invention;

FIG. 38 is a diagram of an electric arrangement of a pixel in the image display apparatus shown in FIG. 37;

FIG. 39 is a timing chart showing the manner in which an image display
5 section operates;

FIG. 40 is a block diagram of an electric arrangement of an image display apparatus according to a twelfth embodiment of the present invention;

FIG. 41 is a diagram of an electric arrangement of a pixel in the image display apparatus shown in FIG. 40;

FIG. 42 is a circuit diagram of an arrangement of a drive circuit for a
10 current control element according to a thirteenth embodiment of the present invention;

FIG. 43 is a timing chart showing the manner in which the drive circuit for the current control element shown in FIG. 42 operates;

FIG. 44 is a graph showing the IDS-VGS characteristics of a drive
15 transistor in the circuit shown in FIG. 42;

FIG. 45 is a graph showing the IL-VL characteristics of the current control element shown in FIG. 42;

FIG. 46 is a graph showing the IDS-VGS characteristics of drive
20 transistors having characteristic variations;

FIG. 47 is a graph showing the transient characteristics of the gate-to-source voltage VGS of drive transistors having characteristic variations;

FIG. 48 is a timing chart showing the manner in which a drive circuit for a
25 current control element according to a fourteenth embodiment of the present invention operates;

FIG. 49 is a circuit diagram of an arrangement of a drive circuit for a current control element according to a fifteenth embodiment of the present invention;

FIG. 50 is a timing chart showing the manner in which the drive circuit for the current control element shown in FIG. 49 operates;

FIG. 51 is a circuit diagram of an arrangement of a drive circuit for a current control element according to a sixteenth embodiment of the present invention;

FIG. 52 is a timing chart showing the manner in which the drive circuit for the current control element shown in FIG. 51 operates;

FIG. 53 is a circuit diagram of an arrangement of a drive circuit for a current control element according to a seventeenth embodiment of the present invention;

FIG. 54 is a circuit diagram of an arrangement of a drive circuit for a current control element according to a nineteenth embodiment of the present invention; and

FIG. 55 is a circuit diagram of an arrangement of a drive circuit for a current control element according to a twentieth embodiment of the present invention.

BEST MODE FOR CARRYING OUT THE INVENTION

Embodiments of the present invention will be described below with reference to the drawings.

First Embodiment:

FIG. 6 is a block diagram of an electric arrangement of an image display apparatus according to a first embodiment of the present invention.

The image display apparatus comprises display panel 50, control circuit 60, signal line driver 70, scanning line driver 80, and resetting signal line driver 90. Display panel 50 comprises an organic EL display, for example, and has a plurality of signal lines $X_1, \dots, X_i, \dots, X_n$ to which gradation pixel data D are applied, a plurality of scanning line $Y_1, \dots, Y_j, \dots, Y_m$ to which scanning signals V are applied, a plurality of resetting signal lines $R_1, \dots, R_j, \dots, R_m$ to which resetting signals Q are applied, and a plurality of pixels 50_{ij} ($i = 1, 2, \dots, n, j = 1, 2, \dots, m$) disposed at points of intersection between signal lines $X_1, \dots, X_i, \dots, X_n$ and scanning lines $Y_1, \dots, Y_j, \dots, Y_m$. Of pixels 50_{ij} , those pixels on scanning lines that are selected by scanning signals V are supplied with gradation pixel data D to display an image.

Control circuit 60 supplies image input signal VD supplied from an external source to signal line driver 70, supplies vertical scanning signal PV to scanning line driver 40, and supplies resetting control signal RA to resetting signal line driver 90. Signal line driver 70 applies gradation pixel data D depending on image input signal VD to signal lines $X_1, \dots, X_i, \dots, X_n$. Scanning line driver 80 successively generates scanning signals V in synchronism with vertical scanning signal PV supplied from control circuit 60, and applies scanning signals V successively in the order of lines, for example, to corresponding scanning line $Y_1, \dots, Y_j, \dots, Y_m$ of display panel 10. Resetting signal line driver 90 applies reset signals Q to respective resetting signal lines $R_1, \dots, R_j, \dots, R_m$ based on resetting control signal RA .

FIG. 7 shows an electric arrangement of pixel 50_{ij} (e.g., $i = 3, j = 2$) and pixels 50_j adjacent thereto in FIG. 6. Pixel $50_{3,2}$ comprises power line 51, ground line 52, selection transistor $53_{3,2}$, holding capacitor $54_{3,2}$, drive transistor

55_{3,2}, pixel display element 56_{3,2}, parasitic capacitor 57_{3,2}, and resetting transistor 58_{3,2}. Power line 51 is supplied with power voltage Vcc with respect to ground line 52. Selection transistor 53_{3,2} comprises an nMOS, for example, and has a drain electrode connected to signal line X₃, a source electrode to node N1, and a gate electrode to scanning line Y₂. Selection transistor 53_{3,2} performs on/off control of a conduction state between signal line X₃ and node N1 based on scanning signal V.

Holding capacitor 54_{3,2} is connected between node N1 and node N2, and holds the voltage between the source and gate electrodes of drive transistor 55_{3,2}. Drive transistor 55_{3,2} comprises an nMOS, for example, and has a drain electrode connected to power line 51 (power voltage Vcc), a source electrode to node N2, and a gate electrode to node N1. Drive transistor 55_{3,2} passes output current I_L, which is controlled based on the voltage between the source and gate electrodes thereof, from power voltage Vcc to node N2. Pixel display element 56_{3,2} has an anode connected to node N2 and a cathode to ground line 52, with parasitic capacitor 57_{3,2} connected between the anode and cathode thereof. Pixel display element 56_{3,2} displays a pixel with a gradation based on output current I_L from drive transistor 55_{3,2}. Pixel display element 56_{3,2} preferably comprises an organic EL element. Resetting transistor 58_{3,2} comprises an nMOS, for example, and has a drain electrode connected to node N2, a source electrode to ground line 52, and a gate electrode to resetting signal line R₂. Resetting transistor 58_{3,2} performs on/off control of a conduction state between node N2 and ground line 52 based on resetting signal Q. Pixels 50_{2,2}, 50_{4,2} which are positioned adjacent to pixel 50_{3,2} also have selection transistor 53_{2,2}, drive transistor 55_{2,2}, selection transistor 53_{4,2}, drive transistor

55_{4,2}, etc., and are of the same arrangement. Other pixels 50_{ij} are also of the same arrangement.

FIG. 8 is a timing chart showing the manner in which image display section 50_{3,2} shown in FIG. 7 operates. FIG. 9 shows the IDS-VGS characteristics of drive transistor 55_{3,2}; FIG. 10 shows the VL-IS characteristics of pixel display element 56_{3,2}; FIG. 11 shows the IDS-VGS characteristics of drive transistors 55_{3,2}, 55_{2,2}, 55_{4,2} of the respective pixels; FIG. 12 shows the transient characteristics of the VGS (gate-to-source voltage) of drive transistors 55_{3,2}, 55_{2,2}, 55_{4,2} of the respective pixels; FIG. 13 shows the transient characteristics of the IDS (drain current) of drive transistors 55_{3,2}, 55_{2,2}, 55_{4,2} of the respective pixels; FIG. 14 shows the IDS-VGS characteristics of drive transistors 55_{3,2}, 55_{2,2}, 55_{4,2} of the respective pixels; and FIG. 15 shows the IDS-VGS characteristics of drive transistors 55_{3,2}, 55_{2,2}, 55_{4,2} of the respective pixels. A control method for the image display apparatus shown in FIG. 6 will be described with reference to these figures.

In non-selection period T1, selection transistor 53_{3,2} and resetting transistor 58_{3,2} are in off-state (non-conductive state). When selection period T2 starts at time t1, scanning signal V is applied to scanning line Y₂ to turn on selection transistor 53_{3,2} (to conductive state) from off-state, and resetting signal Q is applied to resetting signal line R₂ to turn on resetting transistor 58_{3,2} (to conductive state) from off-state. At this time, voltage V_x supplied to signal line X₃ is 0 V which is the same as the ground level. Since selection transistor 53_{3,2} and resetting transistor 58_{3,2} are turned on, holding capacitor 54_{3,2} and parasitic capacitor 57_{3,2} are discharged, bringing gate voltage VG and source voltage VS of drive transistor 55_{3,2} to 0 V (first discharging process). As gate-to-source

voltage VGS of drive transistor 55_{3,2} is 0 V, no current flows between the drain and source of drive transistor 55_{3,2}.

- At time t2, resetting transistor 58_{3,2} is turned off from on-state, and voltage Vx of signal line X₃ changes from 0 V to VDATA, writing gradation pixel data D (pixel data writing process). Immediately thereafter, gate-to-source voltage VGS of drive transistor 55_{3,2} is expressed by:

$$VGS = VDATA \times CL / (CH + CL)$$

where CH: capacitance value of holding capacitor 54_{3,2};

CL: capacitance value of parasitic capacitor 57_{3,2}.

- 10 Source voltage VS of drive transistor 55_{3,2} is expressed by:

$$VS = VDATA \times CH / (CH + CL)$$

- At this time, gate-to-source voltage VGS of drive transistor 55_{3,2} is higher than threshold value VT of drive transistor 55_{3,2} (i.e., $VGS > VT$) on the VGS-IDS characteristics shown in FIG. 19. Inter-terminal VL across pixel display element 56_{3,2}, i.e., source voltage VS of drive transistor 55_{3,2}, is smaller than voltage VOFF at which current IL starts to flow (i.e., $VS < VOFF$), on the VL-IL characteristics shown in FIG. 20. Since gate-to-source voltage VGS of drive transistor 55_{3,2} is higher than threshold value VT ($VGS > VT$), current IL flows between the drain and source of drive transistor 55_{3,2}. Current IL charges parasitic capacitor 57_{3,2}, increasing inter-terminal voltage VL across pixel display element 56_{3,2}, i.e., source voltage VS of drive transistor 55_{3,2}. At the same time, because gate voltage VG drive transistor 55_{3,2} is of constant value VDATA, gate-to-source voltage VGS of drive transistor 55_{3,2} decreases toward threshold value VT. That is, source voltage VS of drive transistor 55_{3,2} approaches [VDATA - VT].

Since drive transistor $55_{3,2}$ and drive transistors $55_{2,2}$, $55_{4,2}$ in FIG. 7 are thin-film transistors formed on a glass substrate (not shown), the VGS-IDS characteristics representing the relationship between drain-to-source current IDS and gate-to-source voltage VGS vary between individual drive transistors $55_{2,2}$, $55_{3,2}$, $55_{4,2}$ as shown in FIG. 21. For example, as shown in FIG. 22, as a sufficient time elapses after the transition of voltage V_x of signal line X_3 from 0 V to VDATA, gate-to-source voltages VGS of drive transistors $55_{2,2}$, $55_{3,2}$, $55_{4,2}$ become threshold values VT_a , VT_b , VT_c , respectively, of drive transistors $55_{2,2}$, $55_{3,2}$, $55_{4,2}$. Drain-to-source currents IDS of drive transistors $55_{2,2}$, $55_{3,2}$, $55_{4,2}$ progressively decrease to 0 from their current values immediately after the pixel data have written, as shown in FIG. 23.

In the present embodiment, at time t_s prior to times t_a , t_b , t_c when gate-to-source voltages VGS of drive transistors $55_{2,2}$, $55_{3,2}$, $55_{4,2}$ become threshold values VT_a , VT_b , VT_c , respectively, selection transistors $53_{2,2}$, $53_{3,2}$, $53_{4,2}$ are turned off, stopping the discharging of charges stored in holding capacitors $54_{2,2}$, $54_{3,2}$, $54_{4,2}$ (second discharging process), whereupon selection period T2 changes to non-selection period T3. After signal charges are written in holding capacitors $54_{2,2}$, $54_{3,2}$, $54_{4,2}$, the stored signal charges are discharged as drain-to-source currents through drive transistors $55_{2,2}$, $55_{3,2}$, $55_{4,2}$. At this time, of drive transistors $55_{2,2}$, $55_{3,2}$, $55_{4,2}$, a transistor with a greater current capacity passes a greater discharged current, so that its gate-to-source voltage VGS drops earlier, and the rate at which the current decreases is greater. On the other hand, a transistor with a smaller current capacity passes a smaller discharged current, so that its gate-to-source voltage VGS drops slower, and the rate at which the current decreases is smaller.

For example, as shown in FIG. 14, when constant signal voltage V_{GS1} corresponding to a set gradation current is written in holding capacitors $54_{2,2}$, $54_{3,2}$, $54_{4,2}$, a current having current value ID_{Sh} flows through the transistor with the greater current capacity, and a current having current value ID_{Sl} flows through the transistor with the smaller current capacity. If the current value of a transistor having an average current capacity is represented by ID_1 , then a variation indicated by $\Delta ID_{S1}/ID_{S1}$ (where, $\Delta ID_{S1} = ID_{Sh} - ID_{Sl}$) occurs. In the present embodiment, as shown in FIG. 15, signal voltage V_{GS2} higher than signal voltage V_{GS1} corresponding to the set gradation current is applied to the gate electrodes of drive transistors $55_{2,2}$, $55_{3,2}$, $55_{4,2}$, storing charges in holding capacitors $54_{2,2}$, $54_{3,2}$, $54_{4,2}$. A variation of current I_L at this time is indicated by $\Delta ID_{S2}/ID_{S2}$.

Thereafter, the charges stored in holding capacitors $54_{2,2}$, $54_{3,2}$, $54_{4,2}$ are discharged for a certain period of time through drive transistors $55_{2,2}$, $55_{3,2}$, $55_{4,2}$ with their gate-to-source voltages V_{GS} dropping in the directions indicated by the respective arrows in FIG. 15. The gate-to-source voltage V_{GS} drops earlier in the transistor with the greater current capacity, and slower in the transistor with the smaller current capacity. Consequently, current variation $\Delta ID_{S3}/ID_{S3}$ after the discharging is stopped is smaller than current variation $\Delta ID_{S2}/ID_{S2}$ immediately after the signal voltages are written.

Since drive transistors $55_{2,2}$, $55_{3,2}$, $55_{4,2}$ have such characteristics that a drive transistor having a larger gate-to-source voltage generally has a smaller drain-to-source current variation, variation $\Delta ID_{S2}/ID_{S2}$ is smaller than variation $\Delta ID_{S1}/ID_{S1}$, resulting in a reduction in the current variation. As a result, when the discharging is stopped at time t_s that is a certain period of time after time t_2

and selection period T2 changes to non-selection period T3, a current variation with respect to the average current, i.e., $\{[(\text{the current flowing through the transistor with the greater current capacity}) - (\text{the current flowing through the transistor with the smaller current capacity})] / (\text{the current flowing through the average transistor})\}$, is smaller than the variation of current IL after the pixel data are written.

In non-selection period T3, selection transistors $53_{2,2}$, $53_{3,2}$, $53_{4,2}$ are turned off, floating the gate electrodes of drive transistors $55_{2,2}$, $55_{3,2}$, $55_{4,2}$. Gate-to-source voltages VGS of drive transistors $55_{2,2}$, $55_{3,2}$, $55_{4,2}$ are held respectively by holding capacitors $54_{2,2}$, $54_{3,2}$, $54_{4,2}$ (charge holding process). Specifically, respective source voltages VS of drive transistors $55_{2,2}$, $55_{3,2}$, $55_{4,2}$ build up as parasitic capacitors $57_{2,2}$, $57_{3,2}$, $57_{4,2}$ are charged, and simultaneously respective gate voltages VG of drive transistors $55_{2,2}$, $55_{3,2}$, $55_{4,2}$ build up through holding capacitors $54_{2,2}$, $54_{3,2}$, $54_{4,2}$ while keeping gate-to-source voltages VGS constant.

When inter-terminal voltages VL (= VS) across pixel display elements $56_{2,2}$, $56_{3,2}$, $56_{4,2}$ reach a voltage that is sufficient to pass currents IL determined by gate-to-source voltages VGS of drive transistors $55_{2,2}$, $55_{3,2}$, $55_{4,2}$, gate voltages VG and source voltages VS of drive transistors $55_{2,2}$, $55_{3,2}$, $55_{4,2}$ stop increasing and become constant. Thereafter, inasmuch as gate-to-source voltages VGS of drive transistors $55_{2,2}$, $55_{3,2}$, $55_{4,2}$ are held respectively by holding capacitors $54_{2,2}$, $54_{3,2}$, $54_{4,2}$, constant currents IL keep flowing through pixel display elements $56_{2,2}$, $56_{3,2}$, $56_{4,2}$. The magnitude of currents IL keep flowing through pixel display elements $56_{2,2}$, $56_{3,2}$, $56_{4,2}$ in non-selection period T3 is adjusted based on the signal charges written in holding capacitors $54_{2,2}$,

54_{3,2}, 54_{4,2} and a set discharge time (an interval between time t₂ and time t_s), and is set such that currents I_L corresponding to the luminance gradation flow.

According to the first embodiment, as described above, signal voltage VGS2 higher than signal voltage VGS1 corresponding to the set gradation

5 current is written in the gate electrodes of drive transistors 55_{2,2}, 55_{3,2}, 55_{4,2}, and the charges stored in holding capacitors 54_{2,2}, 54_{3,2}, 54_{4,2} are discharged for a certain period of time through drive transistors 55_{2,2}, 55_{3,2}, 55_{4,2}. Therefore, variations of the drain-to-source currents of drive transistors 55_{2,2}, 55_{3,2}, 55_{4,2} are reduced. Consequently, variations of the currents flowing through pixel display
10 elements 56_{2,2}, 56_{3,2}, 56_{4,2} are reduced, and so are variations of the luminance gradations of pixels displayed by pixel display elements 56_{2,2}, 56_{3,2}, 56_{4,2}, resulting in the increased quality of the displayed image.

Second Embodiment:

FIG. 16 is a block diagram of an electric arrangement of an image
15 display apparatus according to a second embodiment of the present invention. Common reference characters are assigned to those elements in FIG. 16 which are common to the elements shown in FIG. 6 illustrating the first embodiment.

The image display apparatus according to the present embodiment has control circuit 60B having a different function and display panel 50B having a
20 different arrangement, instead of control circuit 60 and display panel 50 shown in FIG. 6. Control circuit 60B supplies resetting control signal RB having a different timing from resetting control signal RA shown in FIG. 6 to resetting signal line driver 90. Display panel 50B has pixels 50B_{i,j} having a different arrangement, instead of pixels 50_{i,j} shown in FIG. 6. Other details are identical
25 to those shown in FIG. 6.

FIG. 17 is a circuit diagram of an electric arrangement of pixel $50B_{ij}$ (e.g., $i = 3, j = 2$) in the image display apparatus shown in FIG. 16. Common reference characters are assigned to those elements in FIG. 17 which are common to the elements shown in FIG. 7 according to the first embodiment.

5 In pixel $50B_{ij}$, as shown in FIG. 17, resetting transistor $58_{3,2}$ has a drain electrode connected to node N1, and performs on/off control of a conduction state between node N1 and ground line 52 based on resetting signal Q. Other details are identical to those of the pixel shown in FIG. 7. Pixels $50B_{2,2}$, $50B_{4,2}$ and the like (not shown) that are positioned adjacent to pixel $50B_{3,2}$ are of the
10 same structure.

FIG. 18 is a timing chart showing the manner in which image display section $50B_{3,2}$ shown in FIG. 17 operates. A display control method for the image display apparatus shown in FIG. 16 will be described with reference to FIG. 18.

15 In non-selection period T1, selection transistor $53_{3,2}$ is turned off. At time t_1 , resetting signal Q is applied to resetting signal line R_2 to turn on resetting transistor $58_{3,2}$ to on-state (conductive state) from off-state. Since resetting transistor $58_{3,2}$ is turned on, gate voltage VG of drive transistor $55_{3,2}$ is brought to 0 V. Therefore, gate-to-source voltage VGS of drive transistor $55_{3,2}$ becomes
20 a negative voltage, drive transistor $55_{3,2}$ is turned off. At this time, the charges stored in parasitic capacitor $57_{3,2}$ are discharged through pixel display element $56_{3,2}$ to ground line 52 (first discharging process). When a sufficient time elapses after resetting transistor $58_{3,2}$ becomes on-state (conductive state), all the charges stored in parasitic capacitor $57_{3,2}$ are discharged, bringing source
25 voltage VS of drive transistor $55_{3,2}$ to 0 V.

When selection period T2 starts at time t2, resetting transistor 58_{3,2} is turned off, and selection transistor 53_{3,2} is turned on. At this time, voltage Vx of signal line X₃ changes from 0 V to VDATA, writing gradation pixel data D (pixel data writing process). Immediately thereafter, gate-to-source voltage VGS of drive transistor 55_{3,2} is expressed, using capacitance value CH of holding capacitor 54_{3,2} and capacitance value CL of parasitic capacitor 57_{3,2} of the current control element, by:

$$VGS = VDATA \times CL / (CH + CL)$$

Source voltage VS of drive transistor 55_{3,2} is expressed by:

$$VS = VDATA \times CH / (CH + CL)$$

At this time, gate-to-source voltage VGS of drive transistor 55_{3,2} is higher than threshold value VT of drive transistor 55_{3,2} (i.e., $VGS > VT$), as shown in FIG. 9 according to the first embodiment. Inter-terminal voltage VL across pixel display element 56_{3,2}, i.e., source voltage VS of drive transistor 55_{3,2}, is smaller than voltage VOFF at which current IL starts to flow (i.e., $VS < VOFF$), on the VL-IL characteristics shown in FIG. 10 according to the first embodiment.

Subsequently, the image display apparatus according to the second embodiment operates in the same manner as with the first embodiment, and offers the same advantages as with the first embodiment.

Third Embodiment:

FIG. 19 is a block diagram of an electric arrangement of an image display apparatus according to a third embodiment of the present invention. Common reference characters are assigned to those elements in FIG. 19 which are common to the elements shown in FIG. 6 according to the first embodiment.

The image display apparatus shown in FIG. 19 has control circuit 60C

having a different function and display panel 50C having a different arrangement, instead of control circuit 60 and display panel 50 in the image display apparatus shown in FIG. 6. Resetting signal line driver 90 shown in FIG. 6 is dispensed with. Control circuit 60C supplies image input signal VD having a different timing from control circuit 60 to signal line driver 70. Display panel 50C has pixels $50C_{ij}$ having a different arrangement, instead of pixels 50_{ij} shown in FIG. 6. Other details are identical to those of the image display apparatus shown in FIG. 6.

FIG. 20 is a circuit diagram of an electric arrangement of pixel $50C_{ij}$ (e.g., $i = 3, j = 2$) in the image display apparatus shown in FIG. 19. Common reference characters are assigned to those elements in FIG. 20 which are common to the elements shown in FIG. 7 according to the first embodiment.

In pixel $50C_{ij}$, as shown in FIG. 20, resetting transistor $58_{3,2}$ and resetting signal line R_2 shown in FIG. 7 are dispensed with. Other details are identical to those shown in FIG. 7. Pixels $50C_{2,2}$, $50C_{4,2}$ and the like that are positioned adjacent to pixel $50C_{3,2}$ are of the same structure.

FIG. 21 is a timing chart showing the manner in which image display section $50C_{3,2}$ shown in FIG. 20 operates. A display control method for the image display apparatus shown in FIG. 19 will be described with reference to FIG. 21.

In non-selection period T1, selection transistor $53_{3,2}$ is turned off. When selection period T2 starts at time t1, selection transistor $53_{3,2}$ is turned on from off-state. At this time, voltage Vx input to signal line X_3 is 0 V which is the same as the ground level. Since selection transistor $53_{3,2}$ is turned on, charge of holding capacitor $54_{3,2}$ starts being discharged. Similarly, at the same time,

charge of parasitic capacitor $57_{3,2}$ is discharged through pixel display element $56_{3,2}$. When a sufficient time elapses after selection period T2 starts, gate voltage VG and source voltage VS of drive transistor $55_{3,2}$ are brought to 0 V. Since gate-to-source voltage VGS of drive transistor $55_{3,2}$ is 0 V, no current
5 flows between the drain and source of drive transistor $55_{3,2}$.

At time t2, voltage Vx of signal line X_3 changes from 0 V to VDATA, writing gradation pixel data D (pixel data writing process). Subsequently, the image display apparatus according to the third embodiment operates in the same manner as with the first embodiment, and offers the same advantages as
10 with the first embodiment.

Fourth Embodiment:

FIG. 22 is a block diagram of an electric arrangement of an image display apparatus according to a fourth embodiment of the present invention. Common reference characters are assigned to those elements in FIG. 22 which
15 are common to the elements shown in FIG. 6 according to the first embodiment and the elements shown in FIG. 19 according to the third embodiment.

The image display apparatus according to the fourth embodiment has control circuit 60D having a new function added, display panel 50C which is the same as the display panel shown in FIG. 19, and power line voltage switching
20 circuit 100, instead of control circuit 60, display panel 50, and resetting signal line driver 90 in the image display apparatus shown in FIG. 6. Control circuit 60D has a function to supply power line switching control signal VC to power line voltage switching circuit 100, in addition to the function of control circuit 60. Power line voltage switching circuit 100 switches the voltage supplied to power
25 line 51 to power voltage Vcc or ground level (0 V) based on power line

switching control signal VC.

FIG. 23 is a timing chart showing the manner in which image display section 50C_{3,2} (see FIG. 20) operates. A control method for the image display apparatus according to the present embodiment will be described with

5 reference to FIG. 23.

In non-selection period T1, selection transistor 53_{3,2} is turned off. When selection period T2 starts at time t1, selection transistor 53_{3,2} is turned on from off-state. At this time, voltage Vx input to signal line X₃ is a voltage large enough to turn on drive transistor 55_{3,2}. At the same time, the voltage of power
10 line 51 is brought to 0 V. Since drive transistor 55_{3,2} is turned on, charge of parasitic capacitor 57_{3,2} is discharged through this drive transistor 55_{3,2}. After source voltage Vs of drive transistor 55_{3,2} becomes 0 V, voltage Vx input to signal line X₃ becomes 0 V. As selection transistor 53_{3,2} is turned on, charge of holding capacitor 54_{3,2} is discharged, bringing gate voltage VG to 0 V at time t2.
15 Thereafter since gate-to-source voltage VGS of drive transistor 55_{3,2} is 0 V, no current flows between the drain and source of this drive transistor 55_{3,2}.

Next, at time t3, voltage Vx of signal line X₃ changes from 0 V to VDATA, writing gradation pixel data D (pixel data writing process). Subsequently, the image display apparatus according to the fourth embodiment operates in the
20 same manner as with the first embodiment, and offers the same advantages as with the first embodiment.

Fifth Embodiment:

FIG. 24 is a block diagram of an electric arrangement of an image display apparatus according to a fifth embodiment of the present invention.

25 Common reference characters are assigned to those elements in FIG. 24 which

are common to the elements shown in FIG. 6 according to the first embodiment.

The image display apparatus according to the fifth embodiment has display panel 50E having a different arrangement and resetting signal line driver 90E having a different function, instead of display panel 50 and resetting signal line driver 90 in the image display apparatus shown in FIG. 6. Display panel 50E has pixels $50E_{ij}$ having a different arrangement, instead of pixels 50_{ij} shown in FIG. 6. Resetting signal line driver 90E applies resetting signals QE , which are of opposite phase to resetting signals Q , to resetting signal lines $R_1, \dots, R_j, \dots, R_m$, based on resetting control signal RA . In display panel 50E, resetting signals QE are applied to resetting signal lines $R_1, \dots, R_j, \dots, R_m$.

FIG. 25 is a circuit diagram of an electric arrangement of pixel $50E_{ij}$ (e.g., $i = 3, j = 2$) in the image display apparatus shown in FIG. 24. Common reference characters are assigned to those elements in FIG. 25 which are common to the elements shown in FIG. 7 according to the first embodiment.

As shown in FIG. 25, pixel $50E_{ij}$ comprises power line 51, ground line 52, selection transistor $153_{3,2}$, holding capacitor $54_{3,2}$, drive transistor $155_{3,2}$, pixel display element $56_{3,2}$, parasitic capacitor $57_{3,2}$, and resetting transistor $158_{3,2}$. Power line 51 is supplied with power voltage V_{cc} with respect to ground line 52. Selection transistor $153_{3,2}$ has a drain electrode connected to signal line X_3 , a source electrode to node N1, and a gate electrode to scanning line Y_2 . Selection transistor $153_{3,2}$ performs on/off control of a conduction state between signal line X_3 and node N1 based on scanning signal V .

Holding capacitor $54_{3,2}$ is connected between node N1 and node N2, and holds the voltage between the source and gate electrodes of drive transistor $155_{3,2}$. Drive transistor $155_{3,2}$ has a source electrode connected to node N2, a

drain electrode to ground line 52, and a gate electrode to node N1. Drive transistor 155_{3,2} passes output current IL, which is controlled based on the voltage between the source and gate electrodes thereof, from node N2 to ground line 52. Pixel display element 56_{3,2} has an anode connected to power line 51 and a cathode to node N2, with parasitic capacitor 57_{3,2} between the anode and cathode thereof. Pixel display element 56_{3,2} displays a pixel with a gradation based on output current IL from drive transistor 155_{3,2}. Resetting transistor 158_{3,2} has a source electrode to power line 51, a drain electrode to node N2, and a gate electrode to resetting signal line R₂. Resetting transistor 158_{3,2} performs on/off control of a conduction state between node N2 and power line 51 based on resetting signal QE. Other pixels 50_{i,j} are also of the same arrangement.

In the image display apparatus according to the present embodiment, selection transistor 153_{3,2}, drive transistor 155_{3,2}, and resetting transistor 158_{3,2} operate complementarily to selection transistor 53_{3,2}, drive transistor 55_{3,2}, and resetting transistor 58_{3,2} in the image display apparatus shown in FIG. 7 according to the first embodiment. Since the image display apparatus according to the present embodiment operates in the same manner as with the first embodiment, it offers the same advantages as with the first embodiment.

Sixth Embodiment:

FIG. 26 is a block diagram of an electric arrangement of an image display apparatus according to a sixth embodiment of the present invention. Common reference characters are assigned to those elements in FIG. 26 which are common to the elements shown in FIG. 24 according to the fifth embodiment.

The image display apparatus according to the sixth embodiment has control circuit 60F having a different function and display panel 50F having a different arrangement, instead of control circuit 60 and display panel 50E in the image display apparatus shown in FIG. 24. Control circuit 60F supplies
5 resetting control signal RF having a different timing from resetting control signal RA shown in FIG. 24 to resetting signal line driver 90E. Display panel 50F has pixels $50F_{ij}$ having a different arrangement, instead of pixels $50E_{ij}$ in the image display apparatus shown in FIG. 24. Other details are identical to those shown in FIG. 24.

10 FIG. 27 is a circuit diagram of an electric arrangement of pixel $50F_{ij}$ (e.g., $i = 3, j = 2$) in the image display apparatus shown in FIG. 26. Common reference characters are assigned to those elements in FIG. 27 which are common to the elements shown in FIG. 25 according to the fifth embodiment.

In pixel $50F_{ij}$, as shown in FIG. 27, resetting transistor $158_{3,2}$ has a drain
15 electrode connected to node N1, and performs on/off control of a conduction state between node N1 and power line 51 based on resetting signal QE. Other details are identical to those of the pixel shown in FIG. 25. Pixels $50F_{2,2}$, $50F_{4,2}$ and the like (not shown) that are positioned adjacent to pixel $50F_{3,2}$ are of the same structure.

20 In this image display apparatus, selection transistor $153_{3,2}$, drive transistor $155_{3,2}$, and resetting transistor $158_{3,2}$ operate complementarily to selection transistor $53_{3,2}$, drive transistor $55_{3,2}$, and resetting transistor $58_{3,2}$ in the image display apparatus shown in FIG. 17 according to the second embodiment. Since the image display apparatus according to the present
25 embodiment operates in the same manner as with the second embodiment, it

offers the same advantages as with the second embodiment.

Seventh Embodiment:

FIG. 28 is a block diagram of an electric arrangement of an image display apparatus according to a seventh embodiment of the present invention.

- 5 Common reference characters are assigned to those elements in FIG. 28 which are common to the elements shown in FIG. 24 according to the fifth embodiment.

The image display apparatus according to the seventh embodiment has control circuit 60G having a different function and display panel 50G having a
10 different arrangement, instead of control circuit 60 and display panel 50E in the image display apparatus shown in FIG. 24. Resetting signal line driver 90E shown in FIG. 24 is dispensed with. Control circuit 60G supplies image input signal VD having a different timing from control circuit 60 to signal line driver 70. Display panel 50G has pixels $50G_{ij}$ having a different arrangement, instead of
15 pixels $50E_{ij}$ shown in FIG. 24. Other details are identical to those of the image display apparatus shown in FIG. 24.

FIG. 29 is a circuit diagram of an electric arrangement of pixel $50G_{ij}$ (e.g., $i = 3, j = 2$) in the image display apparatus shown in FIG. 28. Common reference characters are assigned to those elements in FIG. 29 which are
20 common to the elements shown in FIG. 25 according to the fifth embodiment.

In pixel $50CG_{ij}$, as shown in FIG. 29, resetting transistor $158_{3,2}$ and resetting signal line R_2 shown in FIG. 25 are dispensed with. Other details are identical to those shown in FIG. 25. Pixels $50G_{2,2}$, $50G_{4,2}$ and the like that are positioned adjacent to pixel $50G_{3,2}$ are of the same structure.

25 In this image display apparatus, selection transistor $153_{3,2}$ and drive

transistor 155_{3,2} operate complementarily to selection transistor 53_{3,2} and drive transistor 55_{3,2} in the image display apparatus shown in FIG. 20 according to the third embodiment. Since the image display apparatus according to the present embodiment operates in the same manner as with the third

5 embodiment, it offers the same advantages as with the third embodiment.

Eighth Embodiment:

FIG. 30 is a block diagram of an electric arrangement of an image display apparatus according to an eighth embodiment of the present invention. Common reference characters are assigned to those elements in FIG. 30 which are common to the elements shown in FIG. 22 according to the fourth

10 embodiment, the elements shown in FIG. 24 according to the fifth embodiment, and the elements shown in FIG. 28 according to the seventh embodiment.

The image display apparatus according to the eighth embodiment has control circuit 60H having a new function added, display panel 50G which is the same as the display panel shown in FIG. 28, and power line voltage switching circuit 100 which is the same as the power line voltage switching circuit shown in FIG. 22, instead of control circuit 60, display panel 50E, and resetting signal line driver 90E in the image display apparatus shown in FIG. 24. Control circuit

15 60H has a function to supply power line switching control signal VH to power line voltage switching circuit 100, in addition to the function of control circuit 60. Power line voltage switching circuit 100 switches the voltage supplied to power line 51 to power voltage Vcc or ground level (0 V) based on power line switching control signal VH.

In this image display apparatus, selection transistor 153_{3,2} and drive transistor 155_{3,2} operate complementarily to selection transistor 53_{3,2} and drive

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transistor 55_{3,2} in the image display apparatus according to the fourth embodiment. Since the image display apparatus according to the present embodiment operates in the same manner as with the fourth embodiment, it offers the same advantages as with the fourth embodiment.

5 Ninth Embodiment:

FIG. 31 is a block diagram of an electric arrangement of an image display apparatus according to a ninth embodiment of the present invention. Common reference characters are assigned to those elements in FIG. 31 which are common to the elements shown in FIG. 6 according to the first embodiment.

10 The image display apparatus according to the ninth embodiment has control circuit 60K having a new function added, display panel 50K having a different arrangement, and control line drivers 110, 120, instead of control circuit 60, display panel 50, and resetting signal line driver 90 in the image display apparatus shown in FIG. 6. Control circuit 60K has a function to supply control signals CA, CB to control line drivers 110, 120, respectively, in addition to the function of control circuit 60. Display panel 50K has pixels 50K_{i,j} having a different arrangement, instead of pixels 50_{i,j} shown in FIG. 6, and also has control lines P₁, ..., P_j, ..., P_m and control lines Q₁, ..., Q_j, ..., Q_m. Control line driver 110 applies control line drive signals α to control lines P₁, ..., P_j, ..., P_m based on control signal CA. Control line driver 120 applies control line drive signals β to control lines Q₁, ..., Q_j, ..., Q_m based on control signal CB.

15 FIG. 32 is a circuit diagram of an electric arrangement of pixel 50K_{i,j} (e.g., i = 3, j = 2) in the image display apparatus shown in FIG. 31. Common reference characters are assigned to those elements in FIG. 32 which are common to the elements shown in FIG. 7 according to the first embodiment.

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As shown in FIG. 32, pixel 50K_j comprises power line 51, ground line 52, selection transistor 153_{3,2}, holding capacitor 54_{3,2}, drive transistor 155_{3,2}, pixel display element 56_{3,2}, parasitic capacitor 57_{3,2}, control transistor 158_{3,2}, and pMOS 159_{3,2}. Selection transistor 153_{3,2} has a drain electrode connected to signal line X₃, a source electrode to node N1, and a gate electrode to scanning line Y₂. Selection transistor 153_{3,2} performs on/off control of a conduction state between signal line X₃ and node N1 based on scanning signal V. Holding capacitor 54_{3,2} is connected between node N1 and power line 51 (power source voltage Vcc), and holds the voltage between the source and gate electrodes of drive transistor 155_{3,2}.

Drive transistor 155_{3,2} has a source electrode connected to power line 51, a drain electrode to node N2, and a gate electrode to node N1. Drive transistor 155_{3,2} passes output current IL, which is controlled based on the voltage between the source and gate electrodes thereof, from power line 51 to node N1. Pixel display element 56_{3,2} has parasitic capacitor 57_{3,2}, and also has an anode connected to node N3 and a cathode to ground line 52. Pixel display element 56_{3,2} displays a pixel with a gradation based on output current IL by drawing output current IL from drive transistor 155_{3,2} through pMOS 159_{3,2} and passing output current IL to ground line 52. Control transistor 158_{3,2} has a source electrode connected to node N1, a drain electrode to node N2, and a gate electrode to control line P₂, and performs on/off control of a conduction state between node N1 and node N2 based on control line drive signal α . pMOS 159_{3,2} has a source electrode connected to node N2, a drain electrode to node N3, and a gate electrode to control line Q₂, and performs on/off control of a conduction state between node N2 and node N3 based on control line drive

signal β . Other pixels $50K_{ij}$ and the like are also of the same arrangement.

FIGS. 33 and 34 are timing charts showing the manner in which image display section $50K_{3,2}$ shown in FIG. 32 operates. A display control method for the image display apparatus according to the present embodiment will be
5 described with reference to these drawings.

As shown in FIG. 33, during a holding period T1, selection transistor $153_{3,2}$, drive transistor $155_{3,2}$, control transistor $158_{3,2}$, and pMOS $159_{3,2}$ are turned off. When selection period T2 starts at time t_1 , scanning signal V is applied to scanning line Y_2 to turn on selection transistor $153_{3,2}$ from off-state,
10 and signal charges of gradation pixel data D from signal line X_3 are stored in holding capacitor $54_{3,2}$ (pixel data writing process).

At time t_s , selection transistor $153_{3,2}$ is turned off and control transistor $158_{3,2}$ is turned on, starting to discharge the charge of holding capacitor $54_{3,2}$ through control transistor $158_{3,2}$ and drive transistor $155_{3,2}$. After the
15 discharging for a certain period of time, control transistor $158_{3,2}$ is turned off and pMOS $159_{3,2}$ is turned on at time t_2 (discharging process). Since gate-to-source voltage VGS of drive transistor $155_{3,2}$ is held by holding capacitor $54_{3,2}$ (pixel data holding process), constant current IL keeps flowing through pixel display element $56_{3,2}$. Subsequently, as with the first embodiment, variations of
20 currents flowing through pixel display elements $56_{2,2}$, $56_{3,2}$, $56_{4,2}$ are reduced, and so are variations of luminance gradations displayed by pixel display elements $56_{2,2}$, $56_{3,2}$, $56_{4,2}$, resulting in an increased quality level of the displayed image.

Further, as shown in FIG. 34, during selection period T2, control
25 transistor $158_{3,2}$ is turned on, writing signal charges of gradation pixel data D

from signal line X_3 in holding capacitor $54_{3,2}$ while the drain and gate electrodes of drive transistor $155_{3,2}$ are being connected (pixel data writing process).

Thereafter, at time t_s , selection transistor $153_{3,2}$ is turned off, starting to discharge the charge of holding capacitor $54_{3,2}$ through control transistor $158_{3,2}$

- 5 and drive transistor $155_{3,2}$. After the discharging for a certain period of time, control transistor $158_{3,2}$ is turned off and pMOS $159_{3,2}$ is turned on at time t_2 (discharging process). Since gate-to-source voltage V_{GS} of drive transistor $155_{3,2}$ is held by holding capacitor $54_{3,2}$ (pixel data holding process), constant current I_L keeps flowing through pixel display element $56_{3,2}$. Subsequently, as
- 10 with the first embodiment, variations of currents flowing through pixel display elements $56_{2,2}$, $56_{3,2}$, $56_{4,2}$ are reduced, and so are variations of luminance gradations displayed by these pixel display elements $56_{2,2}$, $56_{3,2}$, $56_{4,2}$, resulting in an increased quality level of the displayed image.

Tenth Embodiment:

- 15 FIG. 35 is a block diagram of an electric arrangement of an image display apparatus according to a tenth embodiment of the present invention. Common reference characters are assigned to those elements in FIG. 35 which are common to the elements shown in FIG. 31 according to the ninth embodiment.

- 20 The image display apparatus according to the tenth embodiment has display panel 50L having a different arrangement, instead of display panel 50K in the image display apparatus shown in FIG. 31. Display panel 50L has pixels $50L_{ij}$ having a different arrangement, instead of pixels $50K_{ij}$ shown in FIG. 31.

- FIG. 36 is a circuit diagram of an electric arrangement of pixel $50L_{ij}$ (e.g.,
- 25 $i = 3, j = 2$) in the image display apparatus shown in FIG. 35. Common

reference characters are assigned to those elements in FIG. 36 which are common to the elements shown in FIG. 32 according to the ninth embodiment.

In pixel $50L_{3,2}$, as shown in FIG. 36, control transistor $158_{3,2}$ has a drain electrode connected to node N2, and drive transistor $155_{3,2}$ has a gate electrode connected to same node N2. Control transistor $158_{3,2}$ has a source electrode connected to node N1, and drive transistor $155_{3,2}$ has a drain electrode connected to same node N1. Control transistor $158_{3,2}$ performs on/and control of a conduction state between node N1 and node N2 based on control line drive signal α . Other details are identical to those shown in FIG. 32.

This image display apparatus operates in the same manner as the image display apparatus shown in FIG. 34 according to the ninth embodiment, and offers the same advantages as the image display apparatus according to the ninth embodiment.

Eleventh Embodiment:

FIG. 37 is a block diagram of an electric arrangement of an image display apparatus according to an eleventh embodiment of the present invention. Common reference characters are assigned to those elements in FIG. 37 which are common to the elements shown in FIG. 31 according to the ninth embodiment.

The image display apparatus according to the eleventh embodiment has control circuit 60M having a different function and display panel 50M having a different arrangement, instead of control circuit 60K and display panel 50K in the image display apparatus shown in FIG. 31. Control line driver 120 is dispensed with. In control circuit 60M, the function of control circuit 60K to output control signal CB is dispensed with. Display panel 50M has pixels $50M_{ij}$

having a different arrangement, instead of pixels $50K_{ij}$ shown in FIG. 31, and control lines $Q_1, \dots, Q_i, \dots, Q_m$ are dispensed with.

FIG. 38 is a circuit diagram of an electric arrangement of pixel $50M_{ij}$ (e.g., $i = 3, j = 2$) in the image display apparatus shown in FIG. 37. Common
5 reference characters are assigned to those elements in FIG. 38 which are common to the elements shown in FIG. 36 according to the tenth embodiment.

Pixel $50M_{3,2}$ has input drive transistor $258M_{3,2}$ in addition to the arrangement of pixel $50L_{ij}$ shown in FIG. 36, and pMOS $159_{3,2}$ and control line Q_2 are dispensed with. Input drive transistor $258M_{3,2}$ comprises a pMOS and
10 has a source electrode connected to power line 51, a drain electrode to node N1, and a gate electrode to node N3. Input drive transistor $258_{3,2}$ passes an output current controlled based on the voltage between the source and gate electrodes thereof from power line 51 to node N1. Output drive transistor $155_{3,2}$
has a drain electrode connected to node N2, and the anode of pixel display
15 element $56_{3,2}$ is connected to same node N2. The gate electrode of output drive transistor $155_{3,2}$ is connected to node N3. Other details are identical to those shown in FIG. 36.

FIG. 39 is a timing chart showing the manner in which image display section $50M_{3,2}$ shown in FIG. 38 operates. A display control method for the
20 image display apparatus according to the eleventh embodiment will be described with reference to FIG. 39.

As shown in FIG. 39, during holding period T1, selection transistor $153_{3,2}$, control transistor $158_{3,2}$, and pMOS $159_{3,2}$ are turned off. When selection period T2 starts at time t1, scanning signal V is applied to scanning line Y_2 to turn on
25 selection transistor $153_{3,2}$ from off-state, and control line drive signal α is

applied to control line P_2 to turn on control transistor $158_{3,2}$. Signal charges of gradation pixel data from signal line X_3 are stored in holding capacitor $54_{3,2}$ (pixel data writing process).

At time t_s , selection transistor $153_{3,2}$ is turned off and control transistor $158_{3,2}$ is turned on, starting to discharge the charge of holding capacitor $54_{3,2}$ through control transistor $158_{3,2}$ and input drive transistor $258_{3,2}$ (discharging process). After the discharging for a certain period of time, control transistor $158_{3,2}$ is turned off, floating the gate electrode of output drive transistor $155_{3,2}$. Since gate-to-source voltage V_{GS} of output drive transistor $155_{3,2}$ is held by holding capacitor $54_{3,2}$ (pixel data holding process), constant current I_L keeps flowing through pixel display element $56_{3,2}$. In the above discharging process, holding capacitor $54_{3,2}$ is discharged for a certain period of time thereby to reduce variations of currents between the sources and drains of input drive transistor $258_{3,2}$ and output drive transistor $155_{3,2}$. The eleventh embodiment offers the same advantages as the ninth embodiment.

Twelfth Embodiment:

FIG. 40 is a block diagram of an electric arrangement of an image display apparatus according to a twelfth embodiment of the present invention. Common reference characters are assigned to those elements in FIG. 40 which are common to the elements shown in FIG. 37 according to the eleventh embodiment.

The image display apparatus according to the twelfth embodiment has display panel 50N having a different arrangement, instead of display panel 50M in the image display apparatus shown in FIG. 37. Display panel 50N has pixels $50N_{ij}$ having a different arrangement, instead of pixels $50M_{ij}$ shown in FIG. 37.

FIG. 41 is a circuit diagram of an electric arrangement of pixel $50N_{ij}$ (e.g., $i = 3, j = 2$) in the image display apparatus shown in FIG. 40. Common reference characters are assigned to those elements in FIG. 41 which are common to the elements shown in FIG. 38 according to the eleventh embodiment.

In pixel $50N_{ij}$, the gate electrode of input drive transistor $258_{3,2}$ is connected to node N1. Input drive transistor $258_{3,2}$ passes an output current controlled based on the voltage between the source and gate electrodes thereof from power line 51 to node N1. Other details are identical to those shown in FIG. 38. The image display apparatus according to the twelfth embodiment operates in the same manner as with the eleventh embodiment, and offers the same advantages as with the eleventh embodiment.

Thirteenth Embodiment:

FIG. 42 is a circuit diagram of an arrangement of a drive circuit for a current control element according to a thirteenth embodiment of the present invention.

According to the thirteenth embodiment, the drive circuit for the current control element generally comprises selection transistor 4, holding capacitor 5, drive transistor 6, current control element 7 which is typically a pixel display element, and parasitic capacitor 8, all connected between power line 1, ground line 2, and signal line 3.

Selection transistor 4 is in the form of an N-channel field-effect transistor (nMOS), and has a gate electrode connected to a selection line (not shown), a drain electrode to signal line 3, and a source electrode to the gate electrode of drive transistor 6. Holding capacitor 5 is connected between the gate and

source electrodes of drive transistor 6. Drive transistor 6 comprises an nMOS and has its gate electrode connected to the source electrode of selection transistor 4 and one end of holding capacitor 5, a drain electrode to power line 1 and a source electrode to the anode of current control element 7. Current control element 7 comprises a pixel display element such as an organic EL element, and is connected between the source electrode of drive transistor 6 and ground line 2. Current control element 7 emits light at a luminance depending on current I_L from drive transistor 6. Parasitic capacitor 8 comprises a parasitic capacitor across current control element 7.

FIG. 43 is a timing chart showing the manner in which the drive circuit for the current control element operates. Further, FIG. 44 shows the I_{DS} - V_{GS} characteristics of the drive transistor; FIG. 45 shows the I_L - V_L characteristics of the current control element. FIG. 46 shows the I_{DS} - V_{GS} characteristics of drive transistors having characteristic variations; and FIG. 47 shows the transient characteristics of V_{GS} of drive transistors having characteristic variations. Operation of the drive circuit for the current control element according to the present embodiment will be described below with reference to FIGS. 42 to 46.

As shown in FIG. 43, when a selection period of the drive circuit starts, selection transistor 4 is turned to conductive state from cut-off state. At this time, voltage V_{DATA} input to signal line 3 is 0 V which is the same potential as ground line 2. In this state, since selection transistor 4 is in the conductive state, charge of holding capacitor 5 starts to be discharged through signal line 3. At the same time, charge of parasitic capacitor 8 of current control element 7 is discharged through current control element 7.

When a sufficient time elapses after the selection period starts, both gate voltage V_G and source voltage V_S of drive transistor 6 become 0 V. Since gate-to-source voltage V_{GS} of drive transistor 6 is zero, no current flows between the drain and source of drive transistor 6.

5 Then, the input voltage of signal line 3 switches from 0 V to V_A . Immediately after signal line 3 switches from 0 V to V_A , gate-to-source voltage V_{GS} of drive transistor 6 is determined by capacitance value C_S of holding capacitor 5 and capacitance value C_S of parasitic capacitor 8 of current control element 7, according to the following equation:

10
$$V_{GS} = V_A \times C_L / (C_S + C_L) \quad (2)$$

Source voltage V_S of drive transistor 6 is expressed by the following equation:

$$V_S = V_A \times C_S / (C_S + C_L) \quad (3)$$

At this time, gate-to-source voltage V_{GS} of drive transistor 6 needs to be greater than threshold voltage V_T on the I_{DS} - V_{GS} characteristics of the drive transistor shown in FIG. 44. Inter-terminal voltage V_L across current control element 7, i.e., source voltage V_S of drive transistor 6, needs to be smaller than forward rise voltage V_{OFF} on the voltage vs. current characteristics of current control element 7 shown in FIG. 45. That is,

15
$$V_{GS} > V_T \quad (4)$$

20
$$V_S < V_{OFF} \quad (5)$$

Since gate-to-source voltage V_{GS} of drive transistor 6 is greater than threshold voltage V_T , a current flows between the drain and source of drive transistor 6. Because of the current flowing between the drain and source of drive transistor 6, parasitic capacitor 8 of current control element 7 is charged, increasing inter-terminal voltage V_L across current control element 7, i.e.,

source voltage VS of drive transistor 6.

Simultaneously, since gate voltage VG of drive transistor 6 is of constant value VA, gate-to-source voltage VGS of drive transistor 6 decreases toward threshold voltage VT, and source voltage VS of drive transistor 6 approaches
5 (VA - VT).

Since drive transistor 6 is a thin-film transistor or the like formed on a glass substrate, the VGS-IDS characteristics representing the relationship between drain-to-source current IDS and gate-to-source voltage VGS vary greatly as VGS is indicated by VTa, VTb, and VTc with respect to same drain-
10 to-source current IDS, depending on the characteristics of individual transistors 6a, 6b, 6c, as shown in FIG. 46.

As shown in FIG. 47, when a sufficient time elapses, gate-to-source voltages VGS of drive transistors 6a, 6b, 6c change from value $VA \times CL / (CS + CL)$ immediately after signal voltage VA is input to threshold values VTa, VTb,
15 and VTc of the individual transistors. The times until threshold values VTa, VTb, and VTc are reached differ from each other as indicated by Ta, Tb, and Tc. When the sufficient time elapses, no current flows between the drain and source of drive transistor 6, bringing gate-to-source voltage VGS of drive transistor 6 to threshold voltage VT.

$$20 \quad VGS = VT \quad (6)$$

Source voltage VS of drive transistor 6 is expressed by the following equation:

$$VS = VA - VT \quad (7)$$

It is necessary to select capacitance values CS, CL such that source
25 voltage VS of drive transistor 6 is smaller than forward rise voltage VOFF of

current control element 7 on the IL-VL characteristics of current control element 7 shown in FIG. 45.

$$V_S < V_{OFF} \quad (8)$$

Then, voltage VDATA input to signal line 3 is changed from VA to VB

5 where VB is of the same value as VA (non-emitted state) or is of a value greater than VA (emitted state). Voltage difference (VB - VA) at the time VA switches to VB is applied as being divided between capacitance value CS of holding capacitor 5 between the gate and source of drive transistor 6 and capacitance value CL of parasitic capacitor 8 of current control element 7.

10 Therefore, gate-to-source voltages VGS of drive transistor 6 and source voltage VS of drive transistor 6 at this time are given by the following equations:

$$V_{GS} = V_T + (1 - CS/CL) \cdot (VB - VA) \quad (9)$$

$$V_S = VA - V_T + (VB - VA)CS/CL \quad (10)$$

As can be seen from the above equations, since (VGT - VT) is

15 determined by (VB - VA), even if the threshold value of drive transistor 6 suffers a variation, such a variation is compensated for. Thus, the current flowing through current control element 7 is controlled by setting VB and VA to appropriate values.

Then, selection transistor 4 is turned to cut-off state from conductive
20 state, starting a non-selection period. When the non-selection period is started, gate-to-source voltages VGS of drive transistor 6 is held by holding capacitor 5.

Source voltage VS of drive transistor 6 increases as parasitic capacitor 8 of current control element 7 is charged through drive transistor 6, and gate
25 voltage VG of drive transistor 6 simultaneously increases while gate-to-source voltages VGS is being kept constant by holding capacitor 5. When source

voltage VS of drive transistor 6 exceeds forward rise voltage VOFF of current control element 7, current control element 7 starts emitting light, and subsequently keeps emitting light until the non-selection period ends.

When Inter-terminal voltage VL across current control element 7 reaches
5 a voltage that is sufficient to pass current IL determined by gate-to-source voltages VGS of drive transistor 6, gate voltage VG and source voltage VS of drive transistor 6 stop increasing and become constant.

Thereafter, since gate-to-source voltages VGS of drive transistor 6 is held by holding capacitor 5, constant current IL keeps flowing through current
10 control element 7.

The drive circuit for the current control element according to the present embodiment comprises a minimum component arrangement including two transistors, i.e., selection transistor 4 and drive transistor 6, and holding capacitor 5, and is capable of correcting the threshold value of drive transistor 6
15 so as not to be susceptible to a change of the threshold value.

According to the present embodiment, since the number of components of the pixel circuit is 1/2 of the number of components of the conventional drive circuit for the current control element shown in FIG. 4, the aperture ratio of the pixel can be increased, and the manufacturing process is facilitated.
20 Furthermore, since capacitance value CL of parasitic capacitor 8 of current control element 7 is generally greater than capacitance value CS of holding capacitor 5, data can be written in the drive circuit at a lower write voltage for better power consumption.

The drive circuit according to the thirteenth embodiment shown in FIG.
25 42 can be operated differently by different control methods. Embodiments for

such different operations will be described below.

Fourteenth Embodiments:

FIG. 48 is a timing chart showing the manner in which a drive circuit for a current control element according to a fourteenth embodiment of the present invention operates. The drive circuit for the current control element according to the present embodiment is the same as that shown in FIG. 42, but operates differently as its control method is different. Operation of the drive circuit for the current control element according to the fourteenth embodiment will be described below with reference to FIG. 48.

When a selection period of the drive circuit starts, selection transistor 4 is turned to conductive state from cut-off state. At this time, the voltage input to signal line 3 is a voltage large enough to turn on drive transistor 6. At the same time, the potential of power line 1 is set to 0 V.

Since drive transistor 6 is turned on, the charge of parasitic capacitor 8 of current control element 7 is discharged through drive transistor 6. After source voltage V_S of drive transistor 6 becomes 0 V, the voltage of signal line 3 is brought to the ground potential 0 V. Since selection transistor 4 is turned on, the charge of holding capacitor 5 is discharged, bringing gate voltage V_G of drive transistor 6 to 0 V.

Thereafter, the voltage of power line 1 is brought back to the original power line voltage level. Inasmuch as gate-to-source voltage V_{GS} of drive transistor 6 is zero, no current flows between the drain and source of drive transistor 6.

Then, the input voltage of signal line 3 switches from 0 V to V_A .

Subsequently, the drive circuit operates in the same manner as with the

thirteenth embodiment.

As described above, as with the thirteenth embodiment, the drive circuit for the current control element according to the fourteenth embodiment comprises a minimum component arrangement including two transistors, i.e., selection transistor 4 and drive transistor 6, and holding capacitor 5, and is capable of correcting the threshold value of drive transistor 6 so as not to be susceptible to a change of the threshold value. Furthermore, at an initial stage of the selection period, the drive transistor is turned on to bring the potential of power line 1 to 0 V. Therefore, the charges of parasitic capacitor 8 of current control element 7 can be discharged through drive transistor 6 to power line 1. As the source voltage of drive transistor 6 drops quickly, the selection period can be shortened.

Fifteenth Embodiment:

FIG. 49 is a circuit diagram of an arrangement of a drive circuit for a current control element according to a fifteenth embodiment of the present invention. FIG. 50 is a timing chart showing the manner in which the drive circuit operates.

The drive circuit for the current control element shown in FIG. 49 generally comprises selection transistor 4, holding capacitor 5, drive transistor 6, current control element 7 such as a pixel display element, parasitic capacitor 8, and switching transistor 9, all connected between power line 1, ground line 2, and signal line 3. In this drive circuit, the constitutions of power line 1, ground line 2, signal line 3, selection transistor 4, holding capacitor 5, drive transistor 6, current control element 7, and parasitic capacitor 8 are identical to those of the thirteenth embodiment shown in FIG. 42. However, the drive circuit differs from

the thirteenth embodiment in that it additionally has switching transistor 9 as shown in FIG. 49. Switching transistor 9 comprises an nMOS and has a gate electrode connected to the selection line, a drain electrode to the source electrode of drive transistor 6 and one end of holding capacitor 5, and a source electrode connected to ground line 2.

Operation of drive circuit for the current control element according to the present embodiment will be described below with reference to FIGS. 49 and 50.

When a selection period of the drive circuit starts, selection transistor 4 and switching transistor 9 are turned to conductive state from cut-off state under the control of the selection line. At this time, the voltage input to signal line 3 is 0 V which is the same potential as ground line 2. Since selection transistor 4 and switching transistor 9 are turned on, charges of holding capacitor 5 and charges of parasitic capacitor 8 of current control element 7 are discharged, bringing gate voltage V_G and source voltage V_S of drive transistor 6 to 0 V. At this time, since gate-to-source voltage V_{GS} of drive transistor 6 is 0 V, no current flows between the drain and source of drive transistor 6.

Then, switching transistor 9 is turned to cut-off state under the control of the selection line, and the input voltage of signal line 3 switches from 0 V to V_A .

Subsequent operation of the same as with the thirteenth embodiment.

As described above, the drive circuit for the current control element according to the fifteenth embodiment is capable of correcting the threshold value of drive transistor 6 so as not to be susceptible to a change of the threshold value, as with the circuit according to the thirteenth embodiment.

The drive circuit according to the fifteenth embodiment needs switching transistor 9 in addition to the drive circuit according to the thirteenth

embodiment. However, since switching transistor 9 can reset holding capacitor 5 and parasitic capacitor 8 of current control element 7 independently of the writing in holding capacitor 5 by selection transistor 4, holding capacitor 5 and parasitic capacitor 8 can be reset more reliably by selecting a resetting time.

5 Sixteenth Embodiment:

FIG. 51 is a circuit diagram of an arrangement of a drive circuit for a current control element according to a sixteenth embodiment of the present invention. FIG. 52 is a timing chart showing the manner in which the drive circuit for the current control element operates.

10 The drive circuit for the current control element according to the sixteenth embodiment generally comprises selection transistor 4, holding capacitor 5, drive transistor 6, current control element 7, parasitic capacitor 8, and switching transistor 33, all connected between power line 1, ground line 2, and signal line 3. In this drive circuit for the current control element, the
15 constitutions of power line 1, ground line 2, signal line 3, selection transistor 4, holding capacitor 5, drive transistor 6, current control element 7, and parasitic capacitor 8 are identical to those of the thirteenth embodiment shown in FIG. 42. However, the drive circuit differs from the thirteenth embodiment in that it additionally has switching transistor 9 as shown in FIG. 51. Switching transistor
20 33 comprises an nMOS and has a gate electrode connected to a selection line, a drain electrode to the source electrode of drive transistor 6 and one end of holding capacitor 5, and a source electrode connected to ground line 2.

Operation of drive circuit for the current control element according to the sixteenth embodiment will be described below with reference to FIGS. 51 and
25 52.

During a certain period before a selection period of the drive circuit starts, switching transistor 33 is turned to conductive state under the control of the selection line. Since switching transistor 33 is turned on, gate voltage VG drive transistor 6 is zero. Because gate-to-source voltage VGS of drive transistor 6 is a negative voltage, drive transistor 6 is turned to cut-off state. At this time, the charges stored in parasitic capacitor 8 of current control element 7 are discharged current control element 7 to ground line 2.

When a sufficiently long time elapses after switching transistor 33 is turned to conductive state, all the charges stored in parasitic capacitor 8 of current control element 7 are discharged, bringing source voltage VS of drive transistor 6 to 0 V. During this period, selection transistor 4 is turned into cut-off state under the control of the selection line.

When the selection period of the drive circuit starts, switching transistor 33 is turned to cut-off state from conductive state under the control of the selection line. Then, selection transistor 4 is turned to cut-off state from conductive state under the control of the selection line. At this time, VA is input as input voltage VDATA of signal line 3.

Subsequent operation of the same as with the thirteenth embodiment.

As described above, the drive circuit for the current control element according to the present embodiment is capable of correcting the threshold value of drive transistor 6 so as not to be susceptible to a change of the threshold value, as with the circuit according to the thirteenth embodiment. The drive circuit according to the present embodiment needs switching transistor 33 in addition to the drive circuit according to the first embodiment. However, since switching transistor 33 can reset holding capacitor 5 and parasitic

capacitor 8 of current control element 7 independently of the writing in holding capacitor 5 by selection transistor 4, holding capacitor 5 and parasitic capacitor 8 can be reset more reliably by selecting a resetting time.

In the above thirteenth to sixteenth embodiments, the drive circuit for the current control element comprises nMOSs. However, the drive circuit may comprise P-channel field-effect transistors (pMOSs). Embodiments which employ pMOSs will be described below.

Seventeenth Embodiment:

FIG. 53 is a circuit diagram of an arrangement of a drive circuit for a current control element according to a seventeenth embodiment of the present invention.

The drive circuit for the current control element according to the present embodiment generally comprises selection transistor 4A, holding capacitor 5A, drive transistor 6A, current control element 7A, and parasitic capacitor 8A, all connected between power line 1, ground line 2, and signal line 3. Selection transistor 4A comprises a pMOS and has a gate electrode connected to a selection line (not shown), a source electrode to signal line 3, and a drain electrode to the gate electrode of drive transistor 6A. Holding capacitor 5A is connected between the gate and source electrodes of drive transistor 6A. Drive transistor 6A comprises a pMOS and has its gate electrode connected to the drain electrode of selection transistor 4 and one end of holding capacitor 5A, a source electrode to the cathode of current control element 7A, and a drain electrode to ground line 2. Current control element 7A comprises a pixel display element such as an organic EL element, and is connected between power line 1 and the source electrode of drive transistor 6A. Current control

element 7A emits light at a luminance depending on current I_L from drive transistor 6A. Parasitic capacitor 8A comprises a parasitic capacitor across current control element 7A.

5 The drive circuit for the current control element according to the present embodiment differs from the drive circuit according to the thirteenth embodiment shown in FIG. 42 in that selection transistor 4 and drive transistor 6, each comprising an nMOS, are replaced with selection transistor 4A and drive transistor 6A, each comprising a pMOS. Since the voltages applied to the transistors and the current control element are opposite to those in the circuit
10 shown in FIG. 42, the currents also have opposite directions. However, the drive circuit for the current control element according to the present embodiment operates in the same manner as the circuit shown in FIG. 42, and the timing chart shown in FIG. 43 is also applicable here. Therefore, a detailed description of the operation will not be described below.

15 The drive circuit for the current control element according to the present embodiment comprises a minimum component arrangement including two transistors, i.e., selection transistor 4A and drive transistor 6A, and holding capacitor 5A, and is capable of correcting the threshold value of drive transistor 6A so as not to be susceptible to a change of the threshold value.

20 According to the seventeenth embodiment, as with the thirteenth embodiment, the number of components of the pixel circuit is smaller than the number of components of the conventional drive circuit for the current control element, and the aperture ratio of the pixel is greater. The manufacturing process is facilitated, and the power consumption is reduced.

25 Eighteenth Embodiment:

A drive circuit for a current control element according to an eighteenth embodiment of the present invention is of the same arrangement as the drive circuit according to the seventeenth embodiment shown in FIG. 53, but operates differently as its control method is different. Specifically, the drive circuit for the current control element according to the eighteenth embodiment differs from the circuit according to the fourth embodiment in that selection transistor 4 and drive transistor 6, each comprising an nMOS, are replaced with selection transistor 4A and drive transistor 6A, each comprising a pMOS. Since the voltages applied to the transistors and the current control element are opposite to those in the circuit according to the fourteenth embodiment, the currents also have opposite directions. However, the drive circuit for the current control element according to the present embodiment operates in the same manner as the circuit according to the fourteenth embodiment, and the timing chart shown in FIG. 48 is also applicable here. Therefore, a detailed description of the operation will not be described below.

The drive circuit for the current control element according to the present embodiment comprises a minimum component arrangement including two transistors, i.e., selection transistor 4A and drive transistor 6A, and holding capacitor 5A, and is capable of correcting the threshold value of drive transistor 6A so as not to be susceptible to a change of the threshold value, as with the seventeenth embodiment. Furthermore, since the source voltage of drive transistor 6A drops quickly, the selection period can be shortened.

Nineteenth Embodiment:

FIG. 54 is a circuit diagram of an arrangement of a drive circuit for a current control element according to a nineteenth embodiment of the present

Invention.

The drive circuit for the current control element according to the present embodiment generally comprises selection transistor 4A, holding capacitor 5A, drive transistor 6A, current control element 7A, parasitic capacitor 8A, and switching transistor 9A, all connected between power line 1, ground line 2, and signal line 3. In this drive circuit for the current control element, the constitutions of power line 1, ground line 2, signal line 3, selection transistor 4A, holding capacitor 5A, drive transistor 6A, current control element 7A, and parasitic capacitor 8A are identical to those of the seventeenth embodiment shown in FIG. 53. However, the drive circuit differs from the seventeenth embodiment in that it additionally has switching transistor 9A as shown in FIG. 54. Switching transistor 9A comprises a pMOS and has a gate electrode connected to a selection line, a source electrode to power line 1, and a drain electrode to the source electrode of drive transistor 6A and one end of holding capacitor 5A.

The drive circuit for the current control element according to the nineteenth embodiment differs from the drive circuit according to the fifteenth embodiment shown in FIG. 49 in that selection transistor 4, drive transistor 6, and switching transistor 9, each comprising an nMOS, are replaced with selection transistor 4A, drive transistor 6A, and switching transistor 9A, each comprising a pMOS. Since the voltages applied to the transistors and the current control element are opposite to those in the circuit according to the fifteenth embodiment shown in FIG. 49, the currents also have opposite directions. However, the drive circuit for the current control element according to the present embodiment operates in the same manner as the circuit

according to the fifteenth embodiment, and the timing chart shown in FIG. 50 is also applicable here. Therefore, a detailed description of the operation will not be described below.

As with the seventeenth embodiment, the drive circuit for the current
5 control element according to the present embodiment is capable of correcting the threshold value of drive transistor 6A so as not to be susceptible to a change of the threshold value.

The drive circuit according to the nineteenth embodiment needs
switching transistor 9A in addition to the drive circuit according to the
10 seventeenth embodiment. However, since switching transistor 9A can reset holding capacitor 5A and parasitic capacitor 8A of current control element 7A independently of the writing in holding capacitor 5A by selection transistor 4A, holding capacitor 5A and parasitic capacitor 8A can be reset more reliably by selecting a resetting time.

15 Twentieth Embodiment:

FIG. 55 is a circuit diagram of an arrangement of a drive circuit for a current control element according to a twentieth embodiment of the present invention.

The drive circuit for the current control element according to the present
20 embodiment generally comprises selection transistor 4A, holding capacitor 5A, drive transistor 6A, current control element 7A, parasitic capacitor 8A, and switching transistor 33A, all connected between power line 1, ground line 2, and signal line 3. In this drive circuit for the current control element, the constitutions of power line 1, ground line 2, signal line 3, selection transistor 4A,
25 holding capacitor 5A, drive transistor 6A, current control element 7A, and

parasitic capacitor 8A are identical to those of the seventeenth embodiment shown in FIG. 53. However, the drive circuit differs from the seventeenth embodiment in that it additionally has switching transistor 33A as shown in FIG. 55. Switching transistor 33A comprises a pMOSP and has a gate electrode
5 connected to a selection line, a source electrode to power line 1, and a drain electrode to the source electrode of drive transistor 6A and one end of holding capacitor 5A.

The drive circuit for the current control element according to the twentieth embodiment differs from the drive circuit according to the sixteenth
10 embodiment shown in FIG. 51 in that selection transistor 4, drive transistor 6, and switching transistor 33, each comprising an nMOS, are replaced with selection transistor 4A, drive transistor 6A, and switching transistor 33A, each comprising a pMOS. Since the voltages applied to the transistors and the current control element are opposite to those in the circuit according to the
15 sixteenth embodiment shown in FIG. 51, the currents also have opposite directions. However, the drive circuit for the current control element according to the present embodiment operates in the same manner as the circuit according to the sixteenth embodiment, and the timing chart shown in FIG. 52 is also applicable here. Therefore, a detailed description of the operation will
20 not be described below.

As with the seventeenth embodiment, the drive circuit for the current control element according to the present embodiment is capable of correcting the threshold value of drive transistor 6A so as not to be susceptible to a change of the threshold value. The drive circuit according to the twentieth
25 embodiment needs switching transistor 33A in addition to the drive circuit

according to the seventeenth embodiment. However, since switching transistor 33A can reset holding capacitor 5A and parasitic capacitor 8A of current control element 7A independently of the writing in holding capacitor 5A by selection transistor 4A, holding capacitor 5A and parasitic capacitor 8A can be reset
5 more reliably by selecting a resetting time.

While the first to twentieth embodiments of the present invention have been described in detail with reference to the drawings, the specific arrangements are not limited to these embodiments.

For example, selection transistor $53_{3,2}$ and resetting transistor $58_{3,2}$
10 shown in FIG. 7 may be a pMOS. In this case, however, the control signal input to their gate electrodes need to be of opposite phase to the control signal for nMOSs. Similarly, selection transistor $53_{3,2}$ and resetting transistor $58_{3,2}$ shown in FIG. 17 and selection transistor $53_{3,2}$ shown in FIG. 20 may be an nMOS. Selection transistor $153_{3,2}$ and resetting transistor $158_{3,2}$ shown in FIG.
15 25 may be an nMOS. Similarly, selection transistor $153_{3,2}$ and resetting transistor $158_{3,2}$ shown in FIG. 27 and selection transistor $153_{3,2}$ shown in FIG. 29 may be an nMOS.

pMOS $159_{3,2}$ according to the ninth embodiment shown in FIG. 32 and pMOS $159_{3,2}$ according to the tenth embodiment shown in FIG. 36 may be
20 dispensed with to provide substantially the same operation and advantages as with those embodiments. Scanning signal V may be applied to scanning lines $Y_1, \dots, Y_j, \dots, Y_m$ not only in a line sequence, but also in any desired sequence. A feedback resistor may be inserted between the source electrode of drive transistor $55_{3,2}$ shown in FIGS. 7, 17, and 20 and node 2, or between the
25 source electrode of drive transistor $155_{3,2}$ shown in FIGS. 25, 27, and 29 and

node 2, or between the drain electrode thereof and power line 51 for reducing current variations. Likewise, a feedback resistor may be inserted between the source electrode of drive transistor 155_{3,2} shown in FIGS. 32, 36, 38, and 41 and power line 1 for further reducing current variations. The display panels in
5 the embodiments may comprise any current-driven display panel such as a light-emitting diode (LED) array, a field emission display (FED), or the like, other than the organic EL display.

In the fifteenth embodiment, the sixteenth embodiment, the nineteenth embodiment, and the twentieth embodiment, the switching transistor may
10 discharge the charge of holding capacitor 5 and the charge of parasitic capacitor 8 in the non-selection period or in the initial stage of the selection period. They may be discharged in the selection period not only in its terminal stage, but also at any timing therein. If discharged in the initial stage of the selection period, it is necessary to turn off the selection transistor.

15 In each of the embodiments, if the drive transistor comprises an nMOS, the selection transistor and the switching transistor are not limited to nMOSs but may be a desired mixture of nMOS and pMOS. Similarly, if the drive transistor comprises a pMOS, the selection transistor and the switching transistor are not limited to pMOSs but may be a desired mixture of nMOS and
20 pMOS.

Furthermore, the drive circuits for the current control elements according to the thirteenth to twentieth embodiments are also applicable to a drive circuit for a current control element in an image display apparatus wherein a number of current control elements, i.e., pixel display elements, are arrayed two-
25 dimensionally in rows and columns of a matrix. In this case, the drive circuit

also has the same operation and advantages as those of the previous embodiments.

In the fifteenth and sixteenth embodiments, the source electrode of switching transistor 9 is connected to ground line 2. However, the source
5 electrode of switching transistor 9 may be connected to a power line having a different voltage from ground line 2, and the source voltage of drive transistor 6 upon resetting may be set to a voltage other than 0 V for greater circuit design tolerances. The nineteenth and twentieth embodiments may also be similarly modified.

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